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INTELLECTUAL PROPERTY LAW & RELATED MATTERS

DAVID H. HITT  
T. LING CHWANG, PH.D.  
CHARLES W. GAINES

GLENN W. BOISBRUN  
RICHARD N. MCCAIN  
CHRISTOPHER D. DECLUITT

225 UNIVERSITY PLAZA  
275 WEST CAMPBELL ROAD  
RICHARDSON, TEXAS 75080  
U.S.A.

TEL 972/480-8800  
FAX 972/480-8865  
FIRM@HCG-IPLAW.COM

June 5, 1998

Commissioner of Patents  
and Trademarks  
Washington, D.C. 20231

Re: U.S. Patent Application  
"METHOD FOR THE FABRICATION OF CONTACTS IN AN  
INTEGRATED CIRCUIT DEVICE"  
Case Name: MERCHANT 33-3-3

Dear Sir:

Below is our fee calculation for the above-identified patent application:


FOR:	NO. FILED	NO. EXTRA	RATE	FEE
BASIC FEE			\$ 790.00	\$790.00
TOTAL CLAIMS	23-20=	3	\$ 22.00	\$ 66.00
INDEP. CLAIMS	2 - 3=	0	\$ 82.00	\$0
MULTIPLE DEPENDENT CLAIM PRESENTED	0		\$ 270.00	\$0

TOTAL \$856.00

The Commissioner is hereby authorized to charge the fee of \$856.00 or any additional fees that may be required to Deposit Account No. 12-2325.

Very truly yours,

HITT CHWANG & GAINES, P.C.

  
Charles W. Gaines  
Registration No. 36,804

CWG/ljs  
Enclosures

06/05/98

## SMALL ENTITY PATENT APPLICATION TRANSMITTAL

Attorney Docket No.: MERCHANT 33-3-3

Inventor or Application Identifier: Sailesh M. Merchant, et al.

Express Mail Label No.: EM006928805US

Address to: Assistant Commissioner of Patents and Trademarks  
Box Patent Application  
Washington, D.C. 20231

☒ 1. Fee Transmittal Form  
(Submit an original, and a duplicate for fee processing)

☒ 2. Specification 24 total pages  
(preferred arrangement set forth below)  
-Descriptive title of the Invention  
-Cross References to Related Applications  
-Statement Regarding Fed Sponsored R & D  
-Reference to Microfiche Appendix  
-Background of the Invention  
-Brief Summary of the Invention  
-Brief Description of the Drawings (if filed)  
-Detailed Description  
-Claim(s)  
-Abstract of the Disclosure

☐ 3. Drawing(s) (35 USC 113) 5 total pages

☒ 4. Unsigned Oath or Declaration 6 total pages  
a. Newly executed (original or copy)  
b. Copy from a prior application (37 CFR 1.63(d))  
(for continuation/divisional with Box 17 completed)  
DELETION OF INVENTOR(S)  
Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d) and 1.33(b).

☐ 5. Incorporated By Reference (usable if Box 4b is checked)  
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein

☐ 6. Microfiche Computer Program (Appendix)

☐ 7. Nucleotide and/or Amino Acid Sequence Submission  
(if applicable, all necessary)  
a. Computer Readable Copy  
b. Paper Copy (identical to computer copy)  
c. Statement verifying identity of above copies

## ACCOMPANYING APPLICATION PARTS

☐ 8. Assignment Papers (cover sheet & document(s))  
total pages

☐ 9. 37 CFR 3.73(b) Statement          Power of Attorney

☐ 10. English Translation Document (if applicable)

☒ 11. Information Disclosure Statement (IDS)/PTO-1449  
1 Copies of IDS Citations

☐ 12. Preliminary Amendment

☒ 13. Return Receipt Postcard (MPEP 503)  
(should be specifically itemized)

☐ 14. Small Entity Statement(s)  
Statement filed in prior application, Status still proper and desired.

☐ 15. Certified Copy of Priority Document(s)  
(if foreign priority is claimed)

☐ 16. Other:     
    
  

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

Amend the specification by inserting before the first line the sentence: This is a          Continuation,          Divisional,  
         Continuation-in-part (CIP) of prior application serial no.         , filed on         .

18. Correspondence Address

Address all future communications: (May only be completed by applicant, or attorney or agent of record)

Charles W. Gaines  
HITT CHWANG & GAINES, P.C.  
225 University Plaza  
275 West Campbell Road  
Richardson, Texas 75080

June 5, 1998  
Date

Charles W. Gaines  
Charles W. Gaines [Signature]  
Registration No. 36,804

Address of signatory:

HITT CHWANG & GAINES, P.C.  
225 University Plaza  
275 West Campbell Road  
Richardson, Texas 75080  
(972) 480-8800  
Fax: (972) 480-8865

☐ inventor(s)  
☐ filed under 1.34(a)  
☐ assignee of complete interest  
☒ attorney or agent of record

**METHOD FOR THE FABRICATION OF  
CONTACTS IN AN INTEGRATED CIRCUIT DEVICE**

Inventors: Sailesh M. Merchant  
8214 Vineland Oaks Boulevard  
Orlando, Florida 32835

Binh Nguyenphu  
3725 Monlona Drive  
Orlando, Florida 32837

Minseok Oh  
7524 Lindehurst Drive  
Orlando, Florida 32836

Assignee: Lucent Technologies Inc.  
600 Mountain Avenue  
Murray Hill, New Jersey 07974-0636

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**CERTIFICATE OF EXPRESS MAIL**

I hereby certify that this correspondence, including the attachments listed, is being deposited with the United States Postal Service, Express Mail - Post Office to Addressee, Receipt No. EM006928805US, in an envelope addressed to Commissioner of Patents and Trademarks, Washington, D.C. 20231, on the date shown below.

6-5-98  
Date of Mailing

Elizabeth Schumacher  
Typed or printed name of person mailing

Elizabeth Schumacher  
Signature of person mailing

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Charles W. Gaines  
Hitt Chwang & Gaines, P.C.  
225 University Plaza  
275 West Campbell Road  
Richardson, Texas 75080  
972-480-8800

# METHOD FOR THE FABRICATION OF CONTACTS IN AN INTEGRATED CIRCUIT DEVICE

## TECHNICAL FIELD OF THE INVENTION

5 The present invention is directed, in general, to a method for the fabrication of contact plugs and, more specifically, to a method for the fabrication of tungsten plugs in an integrated circuit device.

## BACKGROUND OF THE INVENTION

10 It is well known that integrated circuit fabrication on semiconductor wafers requires the formation of precisely controlled apertures, such as contact openings, that are subsequently filled with a conductive metal and interconnected to create components and very large scale integrated (VLSI) or ultra large scale integrated (ULSI) circuits. The methods for defining and forming such  
15 openings are equally well known to those who are skilled in the art. Market demands for faster and more powerful integrated circuits have resulted in significant growth in the number of devices per  $\text{cm}^2$ , i.e., a higher packing fraction of active devices. This increased packing fraction invariably means that the

interconnections for ever-more-complicated circuits are made to smaller dimensions than before. Thus the aspect ratios of the contacts, i.e., the ratio of the opening depth to the opening diameter, have increased from an order of about 1:1 or 2:1 to a present order of from about 3:1 to as high as about 5:1 for sub-0.25 micron devices.

In the past, aluminum (Al) was deposited in the contact openings over a barrier layer to form contacts. However, some fabrication processes, especially those used to produce CMOS and bipolar semiconductors, now use tungsten (W) deposited within the contact opening over an adhesion/barrier layer of titanium/titanium nitride (Ti/TiN). Such adhesion/barrier layers are needed because of the extremely poor adhesion of tungsten applied by chemical vapor deposition (CVD) on such dielectrics as borophosphosilicate glass (BPSG), silicon dioxide, thermal oxide, and plasma-enhanced oxide and silicon nitride. However, it is known that tungsten adheres well to TiN and that TiN adheres well to Ti and that Ti, in turn, adheres well to the dielectrics listed. Thus, a method that achieves good adhesion of CVD tungsten to the substrate is achieved by interposing layers of titanium and titanium nitride between the dielectric and the tungsten plug.

Referring now to FIGURE 1A, illustrated is a sectional view of a contact opening 110 formed in a dielectric 101 of a conventional

semiconductor wafer 100. The contact opening 110, which is typically cylindrical in shape, comprises a rim 111, a bottom 112, and a wall 113 within the dielectric 101. Underlying the bottom 112 of the contact opening 110 is an active component 120 with a contact surface 122. In order to achieve electrical conductivity between the tungsten plug to be formed and the active component 120, the contact plug bottom 112 is actually the contact surface 122 of the active component 120. The active component 120 may be the source or drain, or gate region of a conventional semiconductor device. The surface upon which the next layer is to be deposited comprises a surface 103 of the dielectric 101 in addition to the contact surface 122 and the contact wall 113.

After forming the contact opening 110 in the dielectric 101 by conventional processes, the process proceeds with the deposition of an adhesion/barrier layer of Ti/TiN on the dielectric surface 103, contact bottom 112 and wall 113. A titanium layer 114 of a field thickness 116a is deposited by physical vapor deposition (PVD) on the contact surface 122, the contact wall 113, and the dielectric surface 103, which may be any of the conventional insulators used in semiconductor manufacturing. Next a titanium nitride layer 115 of a field thickness 116b is deposited by PVD upon the titanium layer 114. For improved contact resistance, enhanced Ti/TiN coverage of the contact surface 122 is achieved using collimation

techniques during PVD. In an advantageous embodiment, a combined thickness 116 of the Ti/TiN layer 114, 115 on the dielectric surface 103 is about 75 nm to about 150 nm. As is shown in FIGURE 1A, the Ti/TiN layers 114, 115 near the rim 111 of the contact opening 110 are quite thin in relation to the other portions of the Ti/TiN layers 114, 115. Because of the irregular topography of the wafer's surface 103, 113, 122, the PVD process deposits more Ti/TiN on the uppermost exposed surface 103 of the dielectric 101 than on the contact surface 122 or the contact wall 113. Therefore, a 100 nm field thickness 116 on the exposed dielectric surface 103 results in a Ti/TiN layer thickness 117 of 20 nm on the contact surface 122. As a consequence of the collimated PVD process, the wall 113 of the contact opening 110 acquires a Ti/TiN layer thickness 118 of about 5 nm to 10 nm. Therefore, the PVD process of depositing layers of titanium and titanium nitride results in a contact plug bottom thickness 117 with about 20% of the field thickness 116, while the contact plug wall thickness 118 is about 5% to 10% of the field thickness 116. The coated substrate is then optimally subjected to a rapid thermal anneal (RTA). Then a nucleation or seed layer of tungsten silicide is applied by silane reduction of tungsten hexafluoride ( $WF_6$ ) at a relatively low pressure.

Following deposition of the TiN layer, the manufacturing

process then proceeds with the blanket chemical vapor deposition of a layer of tungsten that fills the remaining void of the contact opening 110. Tungsten deposition by CVD, the normal process used, involves the use of  $WF_6$ , and subjects the exposed surfaces to fluorine gas and hydrofluoric acid. Referring now to FIGURE 1B, diffusion of fluorine gas into pinhole defects in the TiN layer 115, especially at the contact plug rim 111 where the TiN layer 115 is thinnest, allows the reaction of fluorine with titanium causing the formation of titanium fluoride. The titanium fluoride formation causes the separation of the TiN layer 115 from the Ti layer 114 and a failure 119 to form, as discussed in M. Rutten, et al, Proceedings of the Conference on Advanced Metalization for ULSI Applications, Murray Hill, October 19, 1991, pages 277 to 283, Materials Research Society. In this case, the TiN peels back to form irregular nuclei 130 around which tungsten will form during the subsequent deposition. Consequently, the TiN failure 119 causes an excessive tungsten growth 135 at the location of the defect when compared to tungsten deposition in the contact opening 110 or on the surface 103. Because of their eruption-like form, the excessive tungsten growths 135 are commonly known as volcanoes.

Referring now to FIGURE 2 with continuing reference to FIGURE 1B, illustrated is a schematic representation of an exemplary conventional large aspect ratio contact opening 210 formed in a



dielectric 201 of a sub-0.25 micron integrated circuit. Conventional processes address W-plug formation in contact openings with small aspect ratios. To prevent TiN layer defects 119 and the formation of volcanoes 135, large aspect ratio contacts require greater TiN field thicknesses 216b, i.e.,  $\geq 75$  nm, to achieve a desired bottom thickness 217. These thicker TiN films 215 have increased intrinsic stress, especially when the TiN is deposited at lower temperatures or is collimated. When combined with the thermal stress of the RTA, the thick TiN film 215 intrinsic stresses increase the likelihood that the TiN layer 215 will crack 218 at a microscopic level when annealed. These cracks can cause additional nucleation sites for tungsten growth as previously discussed. In the worst cases, high stresses can cause Ti/TiN stack delamination 219, lack of W-plug adhesion, and ultimately device failure.

However, beyond the referenced usage for sealing minor pinhole imperfections in the TiN layer 215, RTA has the additional highly desirable effect that titanium silicide ( $\text{TiSi}_x$ ) forms at the titanium/dielectric interface 222. The presence of titanium silicide is well known to improve the contact resistance within the contact window 210.

Accordingly, what is needed in the art is a method of fabricating a tungsten plug that enjoys the improved contact

resistance in the contact window provided by RTA without inducing failure of the TiN layer.

## SUMMARY OF THE INVENTION

To address the above-discussed deficiencies of the prior art, the present invention provides a process for fabricating a contact plug in a semiconductor substrate, such as a dielectric, having a contact opening formed therein. In one particular embodiment, the process comprises depositing a barrier layer in the contact opening and on at least a portion of the semiconductor substrate. The barrier layer, in one advantageous embodiment, may comprise two layers of differing material. For example, the barrier layer may comprise a titanium layer that has a titanium nitride layer deposited on it. However other barrier layer materials known to those who are skilled in the art may also be within the scope of the present invention. Moreover, in advantageous embodiments, the barrier layer is deposited using known physical vapor deposition processes.

As design parameters become smaller, the aspect ratio of contacts continues to become larger. For example in sub-0.25 micron technologies, the aspect ratio may range from about 3:1 to about 5:1. This increase in aspect ratio requires a thicker barrier layer of about or equal to 75 nm or greater to obtain substantially defect-free contact metal deposition. A field thickness, which is the barrier layer's thickness on top of the

substrate, is thus required to achieve adequate thickness deposition of the barrier layer within the contact opening. Typically, the barrier layer's thickness within the contact opening will be only about 5% to 20% of the field thickness. For example, if the field thickness is about 100 nm, the barrier layer's thickness within the contact opening may range from about 5 nm to about 20 nm.

The process further includes depositing a contact metal, such as tungsten or some other appropriate contact metal, on the barrier layer within the contact opening and removing a substantial portion of the barrier layer and the contact metal from the semiconductor substrate in the field areas to form the contact, such as a contact plug. In advantageous embodiments, the contact metal is deposited by chemical vapor deposition and removal of the barrier layer, including the field area, and the contact metal is conducted. In an advantageous embodiment, removal may be achieved by conventional chemical/mechanical removal and polishing processes. Alternatively, however, removal may also be performed by known reactive ion etching processes. Generally, there is total removal of both the barrier layer and contact metal from the field area on top of the substrate, and in many processes, total removal is highly desired. In fact, the removal process typically proceeds briefly into the dielectric material in which the contact opening

is formed to insure complete removal of the barrier layer and the contact metal. However, the present invention contemplates that insignificant amounts of one of these materials may remain in some cases where total removal is not complete.

5           After its formation, the contact plug, which includes the barrier layer and the contact metal, is subjected to a temperature sufficient to anneal the barrier layer. In certain embodiments, the process includes subjecting the device to a rapid thermal anneal process in which temperatures ranging from about 600°C to  
10           about 750°C are reached and held for a period ranging from about 5 seconds to about 60 seconds. An advantageous embodiment of the present invention, therefore, recognizes that defects within the contact plug are lessened when the barrier layer is annealed after the field portion of the barrier layer is removed and the contact  
15           plug is formed.

          The foregoing has outlined, rather broadly, preferred and alternative features of the present invention so that those who are skilled in the art may better understand the detailed description of the invention that follows. Additional features of the  
20           invention will be described hereinafter that form the subject of the claims of the invention. Those who are skilled in the art should appreciate that they can readily use the disclosed conception and specific embodiment as a basis for designing or

modifying other structures for carrying out the same purposes of the present invention. Those who are skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the invention in its broadest form.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

5        FIGURES 1A and 1B illustrate schematic representations of semiconductor structures at two stages during formation of tungsten plugs using conventional, prior art techniques;

FIGURE 2 illustrates a schematic representation of an exemplary conventional large aspect ratio contact opening formed in a dielectric of a sub-0.25 micron integrated circuit;

FIGURE 3 illustrates one embodiment of a flow diagram summarizing the steps of forming a metal contact plug in accordance with the principles of the present invention;

FIGURE 4 illustrates a schematic representation of a large aspect ratio contact opening with a tungsten plug formed therein in accordance with the principles of the present invention;

FIGURE 5 illustrates the wafer of FIGURE 4 after chemical mechanical planarization; and

FIGURE 6 illustrates a top view of the wafer of FIGURE 4 after  
20    chemical mechanical planarization.

## DETAILED DESCRIPTION

Referring now to FIGURE 3, illustrated is one embodiment of a flow diagram summarizing the steps of forming a metal contact plug in accordance with the principles of the present invention. The process begins at a Start Step 300. At a first Action Step 310, a contact hole is formed in the dielectric layer of a substrate to expose a portion of an active component of a semiconductor device. At Action Step 320, a layer of Ti is deposited by physical vapor deposition on the exposed surface of the semiconductor wafer. At Action Step 330, a layer of TiN is deposited by PVD on the exposed Ti surface. In one advantageous embodiment, the PVD is accomplished by the collimation of the Ti/TiN films. Those who are skilled in the art are familiar with collimation techniques and the various ways in which the collimation deposition may proceed. At a next Action Step 340, tungsten is deposited on the exposed surface of the semiconductor wafer by CVD. Continuing at Action Step 350, chemical mechanical polishing of the wafer is performed to remove the tungsten, titanium nitride and titanium layers down to the dielectric. At Action Step 360, the wafer is subjected to a rapid thermal anneal. Continuing at Action Step 370, an interconnect layer is deposited to connect the active components. The process concludes at Stop Step 380. One who is skilled in the



art will recognize that Action Step 370 is not essential to the present invention, and is included only for clarity of the next major semiconductor manufacturing step.

Referring now to FIGURE 4, illustrated is a schematic representation of a large aspect ratio contact opening with a tungsten plug formed therein in accordance with the principles of the present invention. A tungsten plug 430 is formed by chemical vapor deposition in a contact opening 410. The tungsten plug 430 is contiguous with a tungsten layer 435 formed atop the TiN layer 415 and the titanium layer 414. The wafer 400 is next subjected to a chemical/mechanical planarization in accordance with Action Step 350 of FIGURE 3. While specific reference is made to chemical/mechanical planarization processes, those who are skilled in the art will readily recognize that other removal processes, such as reactive ion etching processes, may be used to remove the contact metal and barrier layers.

At this point in the present process, one who is skilled in the art should take note that the contact opening 410 differs from the contact opening 210 of FIGURE 2 in that the contact opening 410 has not been subjected to a rapid thermal anneal as in the above-discussed conventional processes. As previously discussed regarding conventional processes, the contact opening 210 of FIGURE 2 is subjected to the damaging effects of a rapid thermal anneal

immediately following the deposition of the Ti/TiN films. Because of the previously discussed titanium fluoride formation, separation of the TiN layer 115 from the Ti layer 114 occurs during the rapid thermal anneal. This separation, in turn, causes a structural failure within the contact to form. The process covered by the present invention is quite different in that the rapid thermal anneal is not conducted until much later in the contact formation process, as discussed below.

Referring now to FIGURE 5 with continuing reference to FIGURE 4, illustrated is the wafer of FIGURE 4 after chemical mechanical planarization. During Action Step 350, the tungsten layer 435, titanium nitride layer 415, and titanium layer 414 are chemically eroded and mechanically removed by abrasion during the chemical mechanical planarization until all traces of the titanium layer 414 have been removed. Thus, a solid tungsten plug 430 reaches from the uppermost surface 530 of the wafer 400 to the contact surface 522 of the active device 520. The wafer 400 will next be subjected to a rapid thermal anneal in accordance with Action Step 360 of FIGURE 3.

Referring now to FIGURE 6 with continuing reference to FIGURE 5, illustrated is a top view of the wafer of FIGURE 4 after chemical mechanical planarization. The wafer 400 of FIGURE 5 is now subjected to a rapid thermal anneal in accordance with Action

Step 360 of FIGURE 3. The length and temperature of the anneal may be in accordance with previously published conventional rapid thermal anneals. In one advantageous embodiment, the rapid thermal anneal is applied for a period ranging from about 5 seconds to about 60 seconds, and at a temperature ranging from about 600°C to about 750°C. As is evident in FIGURE 6, the tungsten plug 430 is surrounded by the titanium nitride layer 415 and the titanium layer 414. One who is skilled in the art will readily recognize that the exposed area of the titanium nitride layer 415 is significantly reduced at this manufacturing state. This TiN is very thin, approximately 5-20% of the original field film thickness. Since this is only a fraction of the former field thickness, when such a thin film 415 is annealed using an RTA after the W-plug 430 is formed, no evidence of cracking of the TiN layer 415 is seen in the contacts. Thus, in one embodiment, the present invention provides a method wherein the RTA is performed only after removal of the W/TiN/Ti layers by CMP, thereby minimizing the exposure of the TiN layer 415 to an annular cross section. Therefore, cracking of the TiN layer 415 is avoided. With the application of the rapid thermal anneal, titanium silicide is formed at the contact surface 522 by the reaction of Ti layer 414 with the active components of the semiconductor device. Since only a fraction of the field thickness is present during the RTA, the advantages of producing

TiSi<sub>x</sub> at the contact surface 522 by a rapid thermal anneal is achieved without the damaging effects associated with conventional processes that have substantially thicker field thicknesses present during the RTA. The processes covered by the present invention, therefore, provide a method for manufacturing a substantially defect-free contact without cracked adhesion/barrier layers.

From the foregoing, it is readily apparent that the present invention provides a process for fabricating a contact plug in a semiconductor substrate having a contact opening formed therein that comprises depositing a barrier layer in the contact opening and on at least a portion of the semiconductor substrate, depositing a contact metal on the barrier layer within the contact opening, removing a substantial portion of the contact metal and barrier layer from the semiconductor substrate and forming a contact plug within the contact opening, and subjecting the contact plug to a temperature sufficient to anneal the barrier layer.

Although the present invention has been described in detail, those who are skilled in the art should understand that they can make various changes, substitutions and alterations herein without departing from the spirit and scope of the invention in its broadest form.

**WHAT IS CLAIMED IS:**

1. A process for fabricating a contact in a semiconductor substrate having a contact opening formed therein, comprising:

depositing a barrier layer in said contact opening and on at least a portion of said semiconductor substrate;

depositing a contact metal on said barrier layer within said contact opening;

removing a substantial portion of said contact metal and said barrier layer from said semiconductor substrate and forming a contact plug within said contact opening;

subjecting said contact plug to a temperature sufficient to anneal said barrier layer.

2. The process of Claim 1 wherein said depositing said barrier layer includes depositing a titanium layer and depositing a titanium nitride layer on said titanium layer.

3. The process of Claim 2 wherein said depositing includes depositing said titanium layer and said titanium nitride layer by physical vapor deposition.

4. The process of Claim 1 wherein said depositing said

2 barrier layer includes depositing said barrier layer in said  
3 contact opening formed in a dielectric and having an aspect ratio  
4 ranging from about 3:1 to about 5:1.

5. The process of Claim 1 wherein said depositing a contact  
2 metal includes depositing tungsten.

6. The process of Claim 5 wherein said depositing includes  
2 depositing said tungsten by chemical vapor deposition.

7. The process of Claim 1 wherein said subjecting includes  
2 subjecting said contact plug to a rapid thermal anneal process.

8. The process of Claim 1 wherein said depositing a barrier  
2 layer includes forming a thickness of said barrier layer ranging  
3 from about 5 nm to about 20 nm within said contact opening and  
4 forming a field area thickness of said barrier layer on said  
5 semiconductor substrate of about 75 nm or greater.

9. The process of Claim 8 wherein said thickness of said  
2 barrier layer within said contact opening is about 5% to about 20%  
3 of said field area thickness.

10. The process of Claim 8 wherein removing a substantial  
portion includes removing said contact metal and said barrier layer  
from said field area thickness.

11. The process of Claim 10 wherein said removing said  
contact metal and said barrier layer includes removing said contact  
metal and said barrier layer by chemical/mechanical polishing  
processes.

12. A process for fabricating an integrated circuit,  
2 comprising:

3 forming an active device on a semiconductor substrate;

4 forming a contact opening in a dielectric deposited on said  
5 active device, said contact opening in electrical contact with said  
6 active device;

7 depositing a barrier layer in said contact opening and on at  
8 least a portion of said semiconductor substrate;

9 depositing a contact metal on said barrier layer within said  
10 contact opening;

11 removing a substantial portion of said contact metal and said  
12 barrier layer from said semiconductor substrate and forming a  
13 contact plug within said contact opening;

14 subjecting said contact plug to a temperature sufficient to  
15 anneal said barrier layer.

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15. The process of Claim 12 wherein said forming said contact  
opening includes forming said contact opening having an aspect  
ratio ranging from about 3:1 to about 5:1.

16. The process of Claim 12 wherein said depositing a contact  
metal includes depositing tungsten.

17. The process of Claim 16 wherein said depositing includes  
depositing said tungsten by chemical vapor deposition.

18. The process of Claim 12 wherein said subjecting includes  
subjecting said contact plug to a rapid thermal anneal process for  
a period ranging from about 5 seconds to about 60 seconds, a  
temperature of said rapid thermal anneal process ranging from about  
600°C to about 750°C.

19. The process of Claim 12 wherein said depositing a barrier  
layer includes forming a thickness of said barrier layer ranging  
from about 5 nm to about 20 nm within said contact opening and  
forming a field area thickness of said barrier layer on said  
semiconductor substrate of about 75 nm or greater.

20. The process of Claim 19 wherein said thickness of said  
2 barrier layer within said contact opening is about 5% to about 20%  
3 of said field area thickness.

21. The process of Claim 19 wherein removing a substantial  
2 portion includes removing said contact metal and said barrier layer  
3 from said field area thickness.

22. The process of Claim 21 wherein said removing said  
4 contact metal and said barrier layer includes removing said contact  
5 metal and said barrier layer by chemical/mechanical polishing  
6 processes.  
7  
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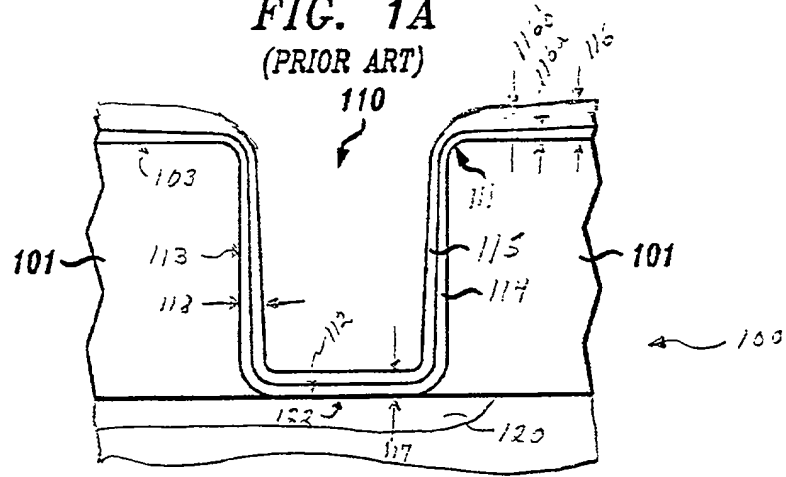
23. The process of Claim 12 wherein forming said active  
9 device includes forming an active device having a design width of  
10 about 0.25 microns or less.  
11

METHOD FOR THE FABRICATION OF  
CONTACTS IN AN INTEGRATED CIRCUIT DEVICE

ABSTRACT OF THE DISCLOSURE

5 The present invention provides a process for fabricating a  
contact plug in a semiconductor substrate having a contact opening  
formed therein that comprises depositing a barrier layer in the  
contact opening and on at least a portion of the semiconductor  
substrate, depositing a contact metal on the barrier layer within  
the contact opening, removing a substantial portion of the contact  
metal and the barrier layer from the semiconductor substrate and  
forming a contact plug within the contact opening, and subjecting  
the contact plug to a temperature sufficient to anneal the barrier  
layer.

**FIG. 1A**  
(PRIOR ART)



**FIG. 1B**  
(PRIOR ART)

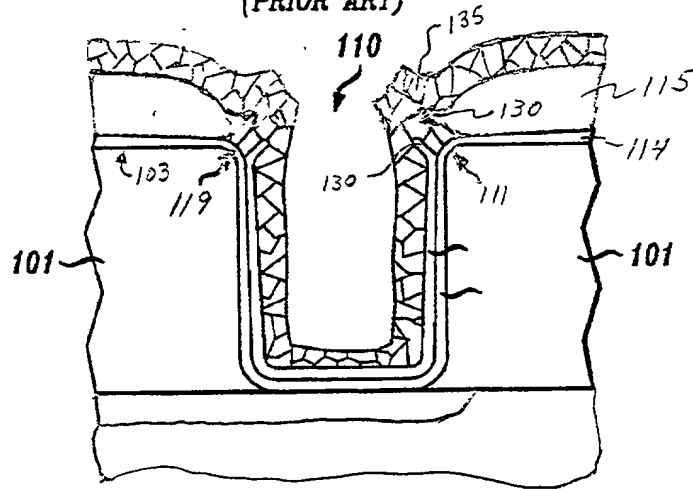
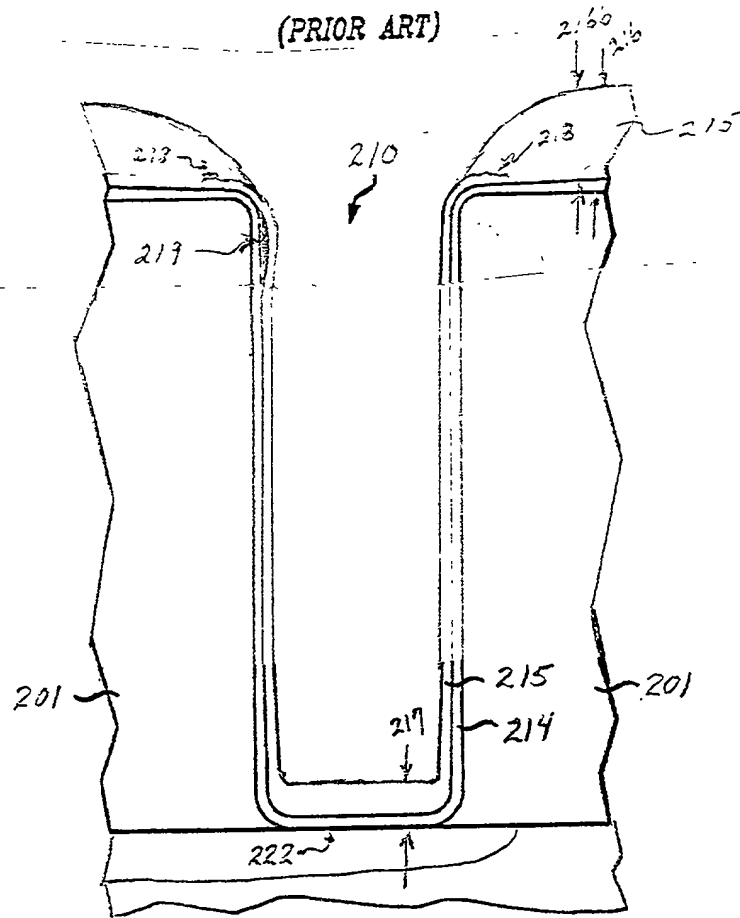


FIG. 2  
(PRIOR ART)



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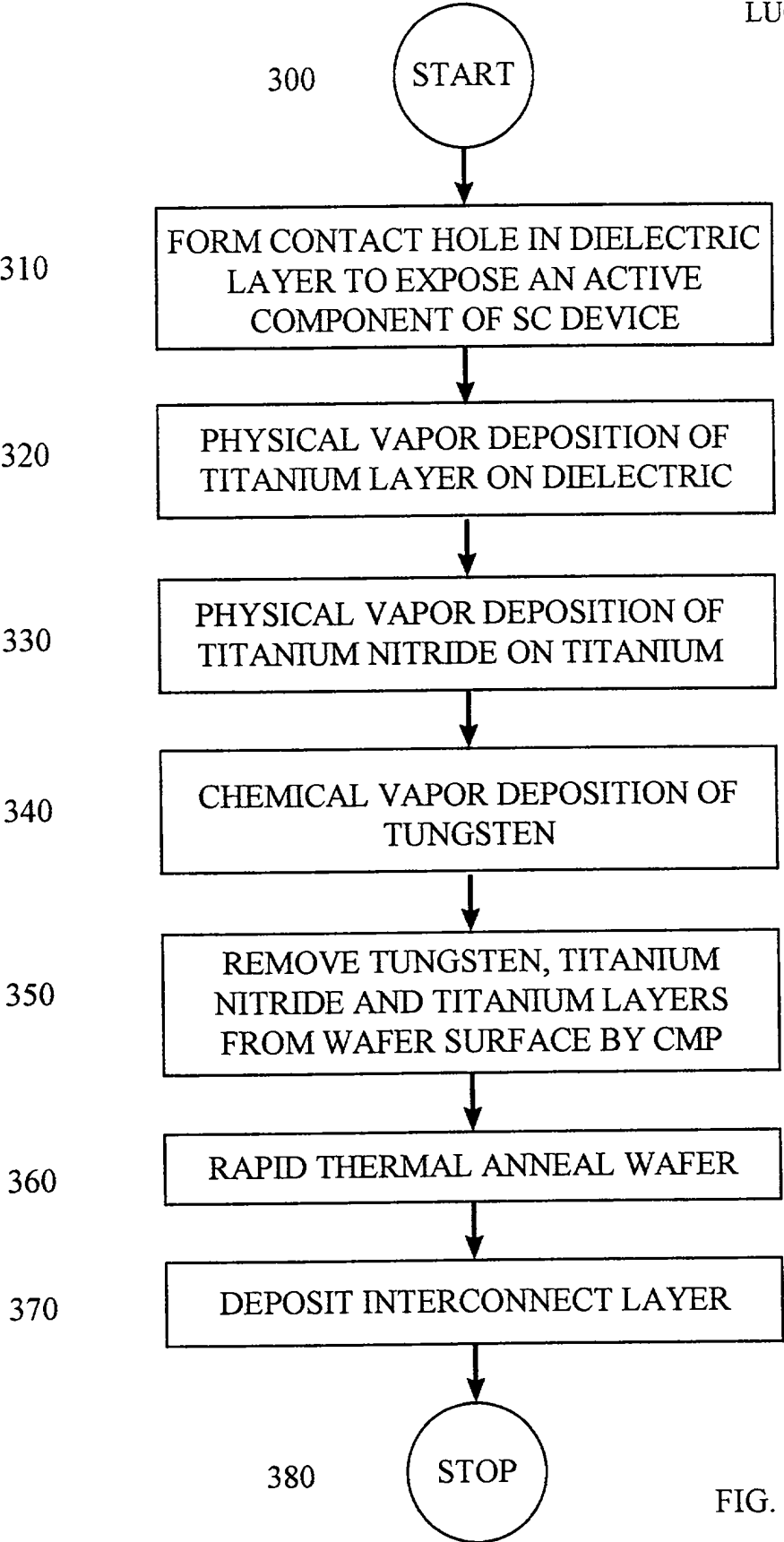


FIG. 3

FIG 4

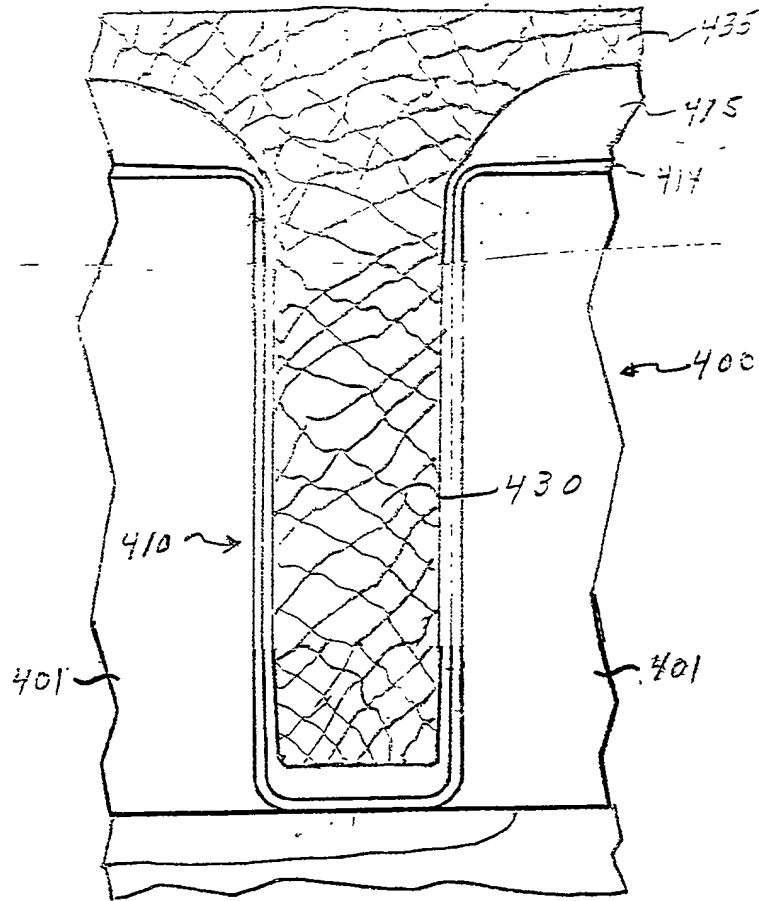


FIG. 5

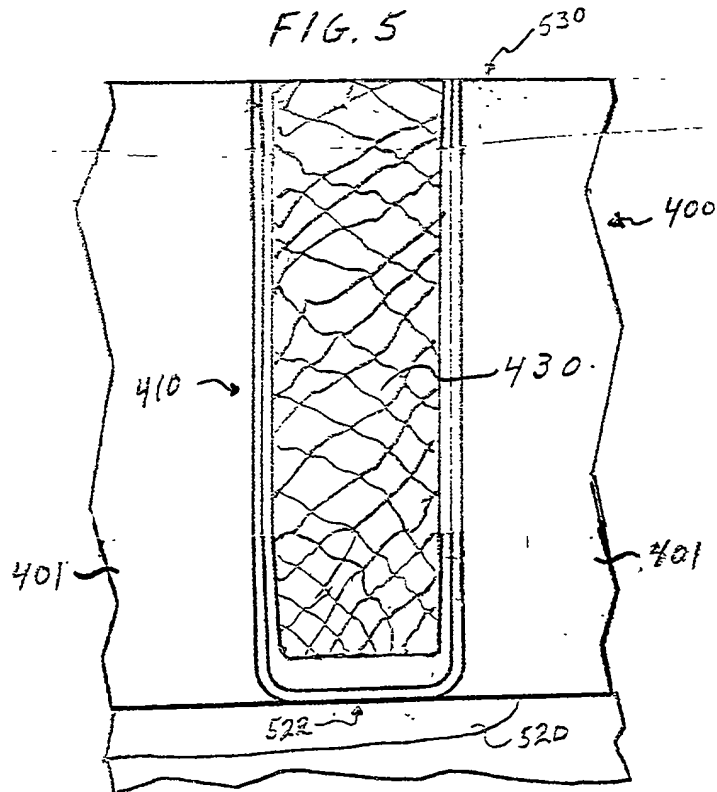
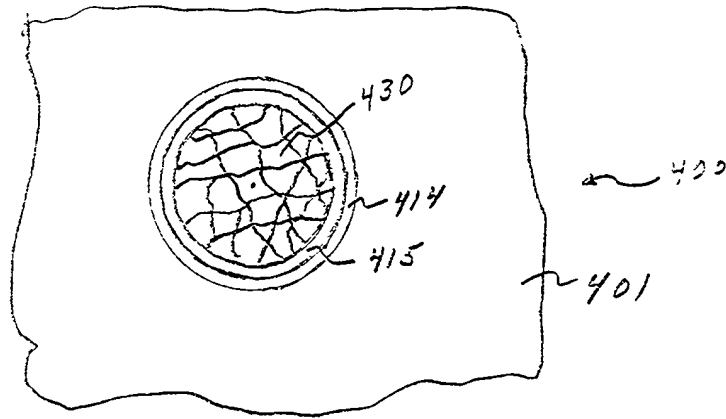


FIG 6



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**IN THE UNITED STATES  
PATENT AND TRADEMARK OFFICE**

**Declaration and Power of Attorney**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled "METHOD FOR THE FABRICATION OF CONTACTS IN AN INTEGRATED CIRCUIT DEVICE," the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

None

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

None

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and

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that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorney(s) with full power of substitution and revocation, to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

Robert R. Axenfeld	(Reg. No. 37276)
Steven R. Bartholomew	(Reg. No. 34771)
Lester H. Birnbaum	(Reg. No. 25830)
Richard J. Botos	(Reg. No. 32016)
Kenneth M. Brown	(Reg. No. 37590)
Donald P. Dinella	(Reg. No. 39961)
Brian K. Dinicola	(Reg. No. 36122)
Martin I. Finston	(Reg. No. 31613)
James H. Fox	(Reg. No. 29379)
Mony R. Ghose	(Reg. No. 38159)
Jimmy Goo	(Reg. No. 36528)
John M. Harman	(Reg. No. 38173)
Donald E. Hayes Jr.	(Reg. No. 33245)
Michael B. Johannesen	(Reg. No. 35557)
Frederick B. Luludis	(Reg. No. 26299)
Christopher N. Malvone	(Reg. No. 34866)
Scott W. McLellan	(Reg. No. 30776)
Geraldine Monteleone	(Reg. No. 40097)
John C. Moran	(Reg. No. 30782)
Michael A. Morra	(Reg. No. 28975)
Claude R. Narcisse	(Reg. No. 38979)
Katharyn E. Olson	(Reg. No. 37693)
Joseph J. Opalach	(Reg. No. 36229)
Eugen E. Pacher	(Reg. No. 29964)
Jack R. Penrod	(Reg. No. 31864)
Gregory C. Ranieri	(Reg. No. 29695)
John T. Rehberg	(Reg. No. 29207)
Scott J. Rittman	(Reg. No. 39010)
Eugene J. Rosenthal	(Reg. No. 36658)
Robert E. Rudnick	(Reg. No. 36260)
Bruce S. Schneider	(Reg. No. 27949)
Nicholas J. Skarlatos	(Reg. No. 37941)
Ronald D. Slusky	(Reg. No. 26585)
David L. Smith	(Reg. No. 30592)

Thomas Stafford	(Reg. No. 24767)
Michael J. Urbano	(Reg. No. 24522)
David Volejnicek	(Reg. No. 29355)
Charles L. Warren	(Reg. No. 27407)
Eli Weiss	(Reg. No. 17765)
Dennis J. Williamson	(Reg. No. 32338)
Samuel R. Williamson	(Reg. No. 28768)

Please address all correspondence to Charles W. Gaines, Hitt Chwang & Gaines, P.C., 225 University Plaza, 275 West Campbell Road, Richardson, Texas 75080. Telephone calls should be made to Charles W. Gaines of Hitt Chwang & Gaines, P.C. by dialing (972) 480-8800.

Full name of first joint inventor: Sailesh M. Merchant

Inventor's signature \_\_\_\_\_ Date \_\_\_\_\_

Residence: City of Orlando  
County of Orange  
State of Florida

Citizenship: India

Post Office Address: 8214 Vineland Oaks Blvd.  
Orlando, Florida 32835

Full name of second joint inventor: Binh Nguyenphu

Inventor's signature \_\_\_\_\_ Date \_\_\_\_\_

Residence: City of Orlando  
County of Orange  
State of Florida

Citizenship: United States of America

Post Office Address: 3725 Monlona Drive  
Orlando, Florida 32837

Full name of third joint inventor: Minseok Oh

Inventor's signature \_\_\_\_\_ Date \_\_\_\_\_

Residence: City of Orlando  
County of Orange  
State of Florida

Citizenship: Korea

Post Office Address: 7524 Lindenhurst Drive  
Orlando, Florida 32836